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# OBSERVATIONS ON THE ECOLOGY AND LIFE CYCLE OF *PROCHRISTIANELLA PENAEI* KRUSE (CESTODA: TRYPANORHYNCHA)*

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ABSTRACT: Examinations of *Penaeus aztecus* and *P. setiferus* from the Galveston Bay area show *Prochristianella penaei* plerocerci to be common in these shrimp, thus extending the known range of this tapeworm to the western Gulf of Mexico. Two years of repeated sampling of shrimp from Clear Lake, a secondary bay in the Galveston Bay system, showed patterns of infection which provided useful leads both to the ecological area where infection of shrimp occurs and the identity of the parasite's definitive host. The relationship found between shrimp size and incidence of infection, when considered with the known migratory habits of *Penaeus aztecus* and *P. setiferus*, suggests that these decapods are uninfected when they enter the bay and are usually infected by the time they leave. Since this pattern showed a rather brackish bay (1‰ to 10‰) to be a probable site in which infection of shrimp takes place, it was assumed that (1) the first intermediate host of *Prochristianella penaei* also inhabits such areas and (2) the range of the elasmobranch final host includes low salinity areas, permitting completion of this cestode's life cycle. The latter point postulates a broad salinity tolerance range for the final host. Discovery of the adult tapeworm in *Dasyatis sabina*, a ray noted for the extent of its salinity tolerance, lends support to these assumptions.

Despite our long acquaintance with penaeid shrimp (e.g., Linnaeus provided the first description of the white shrimp, *Penaeus setiferus*), and the continually increasing commercial importance of these animals during the last 40 years, thorough examinations of shrimp for parasites have not been reported prior to the Florida studies of Hutton et al. and Kruse, both in 1959. As a result, our present knowledge of the ecology and life cycles of shrimp parasites is slight. This situation is particularly true in the western Gulf of Mexico, one of the most productive shrimp habitats in the world.

In 1959, Dr. Edward Chin brought to me for identification a small, white cyst in the digestive gland of a shrimp collected from Galveston Bay. The cyst proved to be the plerocercus stage of a trypanorhynch cestode identical to that described by Kruse (1959) as *Prochristianella penaei*. Since no information is available on the incidence of this parasite except in Florida waters, a survey was undertaken to determine the frequency with which the worm occurred in shrimp from the Galveston area. In addition, the dearth of information on trypanorhynch life cycles coupled with the need for a better understanding of shrimp ecology suggested a search for the undescribed stages in the life history of *P. penaei*. The results of the survey work showed seasonal patterns of infection which proved useful in ascertaining both the ecological area where infection of shrimp occurs and the identity of the parasite's definitive host.

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## MATERIALS AND METHODS

In selecting possible sites for regular sampling stations, consideration was given to the fact that both *Penaeus aztecus*, the brown shrimp, and *P. setiferus*, the white shrimp, are migratory in habit. The available life cycle information on these locally abundant species (Viosca, 1920; Weymouth, Lindner, and Anderson, 1933; and Burkenroad, 1934, 1939) indicates that spawning and larval development occur only offshore, the resulting postlarvae (about 0.5 inch in length) moving shoreward to bays, where they spend several months of rapid growth to subadult size (3 to 5 inches long) before migrating offshore again to attain adulthood and spawn. Thus, bays appear to provide important pasture areas for these animals prior to their return to the open waters of the Gulf of Mexico where they were spawned.

Since Clear Lake, a secondary bay in the Galveston Bay complex (Fig. 1), was being sampled for shrimp fairly regularly by other workers at this laboratory, and had been shown to harbor an abundance of both *P. aztecus* and *P. setiferus* (Chin, 1961), it was selected as an area for regular sampling. Monthly mean bottom temperatures for Clear Lake range from 10 to 30 C, and bottom salinity is usually between 1‰ and 10‰.

Offatts Bayou, another secondary bay in the Galveston Bay system, has a comparable temperature regime but a higher salinity range (15‰

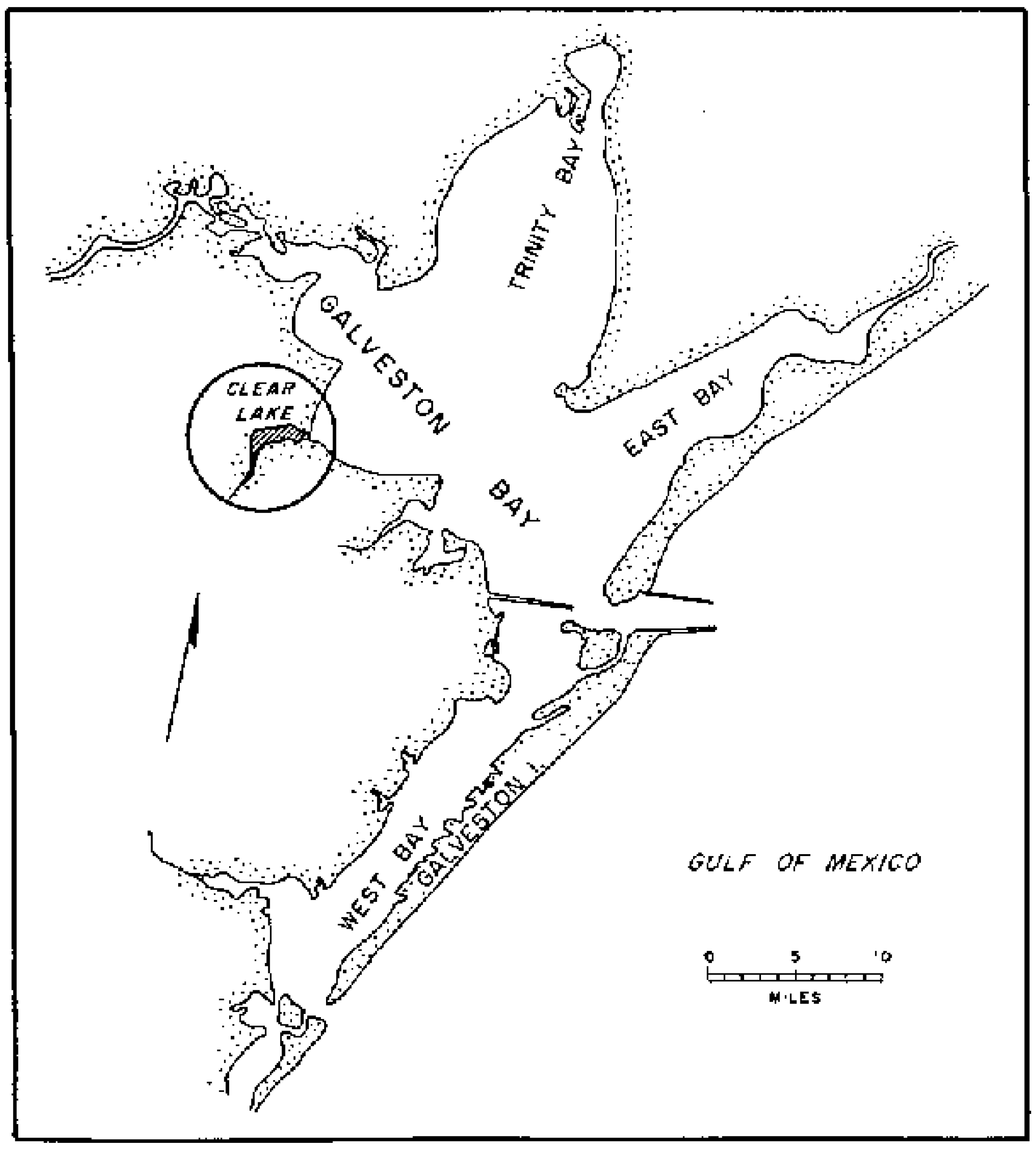


FIGURE 1. Map of Galveston Bay area.

to 29‰). Since this area was also being sampled with some regularity, it was included for comparison with Clear Lake in regard to incidence and intensity of shrimp infection with *Prochristianella penaei*.

The Galveston Bay shrimp were collected with a 10-ft otter trawl (1-inch, stretched-mesh size) towed at 4 to 6 knots for 5 min by outboard motorboat. The offshore samples were taken by the usual commercial method, which employs 40-ft otter trawls. When shrimp catches by either method exceeded 50 animals, approximately 50 shrimp were subsampled from the total catch. As a result, the numbers of shrimp examined could not be considered indices of abundance except when the total (*Penaeus aztecus* plus *P. setiferus*) was less than 48.

When time did not permit their examination on the day of collection, shrimp were stored in a refrigerator at 2 to 4 C for a day or two. The cestodes remained alive under this treatment. For examination, the digestive gland was carefully removed to a large petri dish and thoroughly broken up by repeatedly squirting the tissue out of a medicine dropper. This procedure readily comminutes the follicular tissue of the gland, freeing any helminths present. That region of the shrimp's body cavity which had been occupied by the hepatopancreas was also thoroughly flushed with jets of saline solution from a medicine dropper. All cystlike bodies yielded by this treatment were removed to smaller dishes of saline and cestode plerocerci were identified and counted under a dissecting microscope at 13 and 54 ×. These larvae were fixed with AFA or Bouin's fluid. Final identification was made on picro-carmine stained and cleared specimens. Tentacular armature was examined by phase contrast microscopy at 500 and 1,200 ×, and compared with that figured by Kruse (1959) in his description of *Prochristianella penaei*.

Elasmobranchs were examined within an hour after death. In each case, the spiral valve was removed and opened under saline solution in a large petri dish. Worms were removed either by flushing with saline or pulling gently with a probe inserted between the scolex and intestinal mucosa. Adult worms were fixed in AFA, stained with picro-carmine, and mounted in balsam.

## RESULTS

The overall incidence data show *Prochristianella penaei* to be a common parasite in shrimp of the Galveston area. Of the total 2,097 shrimp examined, 1,006, or 48%, contained this cestode, the infection being quite common in each of the sampling years (Table I). Both of the two most abundant species of shrimp were found to be infected. Overall, 45% of the brown shrimp, *Penaeus aztecus*, and 50% of the white shrimp, *P. setiferus*, contained the tapeworm. Furthermore, infected shrimp were found offshore as well as in various parts of the Galveston Bay complex, suggesting that the worm is widely distributed throughout this area.

The Offatts Bayou shrimp samples revealed a very low and spotty availability of both *P. aztecus* and *P. setiferus*, paralleling the findings of Inglis (1963). As a result, the infection data for this bay are categorized only as to host species and year (Table I). On the other hand, shrimp were found in Clear Lake on every sampling trip during a period extending from April or May through November. Each year, the Clear Lake samples indicated the presence of brown shrimp before white shrimp, the former appearing in April or May, the latter arriving in June (Fig. 2). It has been noted that this sequence of events characterizes not only Galveston Bay in general (Leary and Compton, 1961) but specifically Clear Lake (Chin, 1961). As indicated in Figure 2, *Prochristianella penaei* was present in Clear Lake shrimp throughout most of the period of shrimp abundance.

The incidence of infection in Clear Lake shrimp of 1960 and 1961 was found to increase with the size of shrimp (Fig. 3). In 1960, the rates of increase in infection incidence for *P. aztecus* and *P. setiferus* were comparable, the maximum level of about 80% being reached

TABLE I. *Infection of brown and white shrimp with* Prochristianella penaei *in the Galveston Bay area.*

| Year | Area | *Penaeus aztecus* | | | | | *Penaeus setiferus* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Size range carapace length (mm) | Number shrimp examined | Number shrimp infected | Per cent incidence | Worms per shrimp (no. and range) | Size range carapace length (mm) | Number shrimp examined | Number shrimp infected | Per cent incidence | Worms per shrimp (no. and range) |
| 1959 | 10–30 miles offshore | 25–47 | 99 | 33 | 33 | 1.5 (0–17) | 24–32 | 50 | 35 | 70 | 1.9 (0–8) |
| | Miscellaneous parts of Galveston Bay | 16–34 | 21 | 13 | 62 | 1.9 (0–14) | 13–39 | 105 | 92 | 88 | 5.5 (0–29) |
| | Clear Lake | 10–22 | 101 | 13 | 13 | 0.1 (0–2) | 7–23 | 100 | 28 | 28 | 0.6 (0–8) |
| 1960 | Miscellaneous parts of Galveston Bay | 8–17 | 90 | 35 | 39 | 0.6 (0–5) | – | – | – | – | – |
| | Clear Lake | 8–20 | 104 | 54 | 52 | 2.8 (0–18) | 6–24 | 267 | 133 | 50 | 1.5 (0–16) |
| | Offatts Bayou | 20–24 | 2 | 1 | – | – | 7–30 | 105 | 39 | 37 | 1.2 (0–40) |
| 1961 | Miscellaneous parts of Galveston Bay | – | – | – | – | – | 23–31 | 7 | 7 | 100 | 8.4 (4–16) |
| | Clear Lake | 2–25 | 230 | 120 | 52 | 4.3 (0–32) | 7–29 | 441 | 189 | 43 | 1.5 (0–29) |
| | Offatts Bayou | 5–30 | 173 | 99 | 57 | 2.2 (0–26) | 4–31 | 202 | 115 | 57 | 1.7 (0–12) |

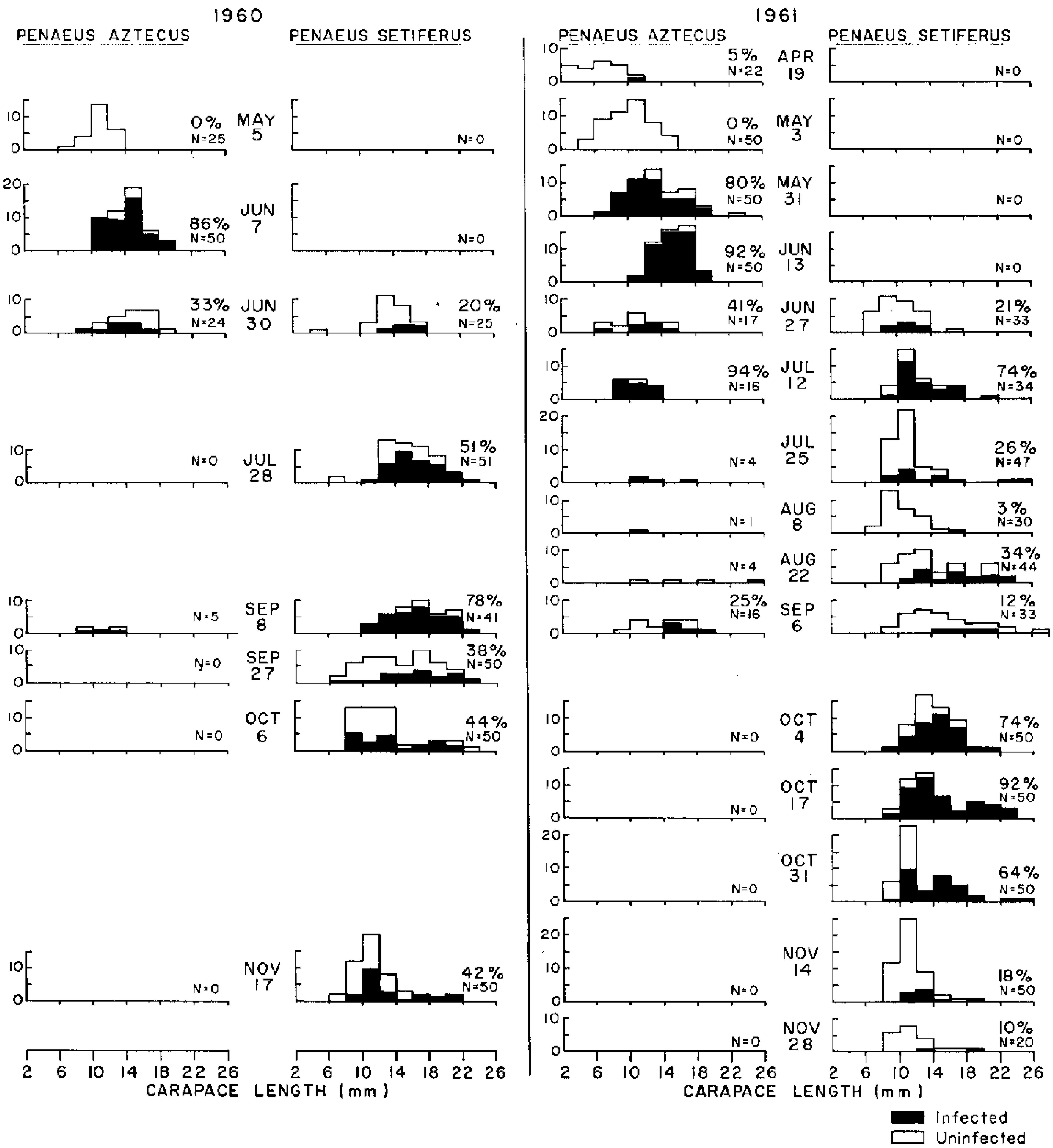


FIGURE 2. Seasonal incidence of shrimp and *Prochristianella penaei* plerocerci in Clear Lake.

in shrimp averaging 20 to 21 mm carapace length. In 1961, on the other hand, *P. aztecus* of about 9 to 14 mm carapace length were more frequently infected than *P. setiferus* of comparable size. Above 14 mm, the incidence of infection leveled off at 70 to 75% for both species.

In both 1960 and 1961, the relationship of shrimp size to intensity of infection (or number of worms per host) showed striking differences between the two species of shrimp (Fig. 4). At smaller size ranges, *P. aztecus* showed a very rapid increase in intensity of infection with increasing size. However, above 13 to 15 mm carapace length, the number of worms per shrimp failed to increase further. In both years, brown shrimp showed the more rapid increase in intensity of infection and were generally more heavily parasitized than white shrimp of comparable size. White shrimp also showed increasing intensity of infection with increasing size of host in both years. In 1960, this relationship continued throughout the size range, but in 1961 a peak was reached at about 18 mm carapace length, and white shrimp larger than this contained fewer worms. The

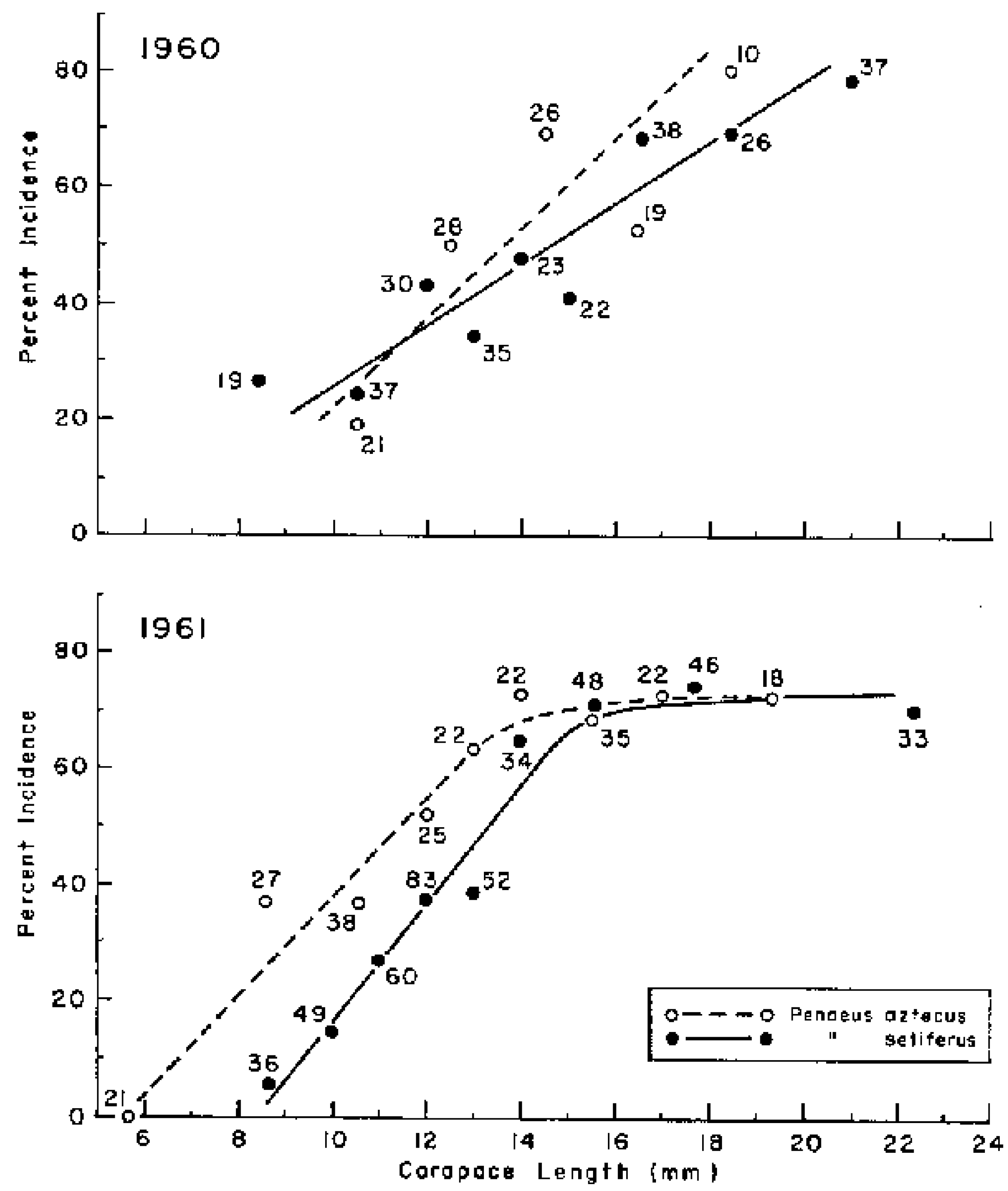


FIGURE 3. Incidence of *Prochristianella penaei* in shrimp of various sizes from Clear Lake. The number of shrimp represented by each point is indicated by the number adjacent to it.

1959 shrimp samples from Clear Lake were too few and scattered to demonstrate reliable patterns.

## DISCUSSION

The present results clearly establish *Prochristianella penaei* as a common parasite of both species of commercially important shrimp in the Galveston area. This fact extends the known range of this tapeworm to the northwestern Gulf of Mexico. Although *P. penaei* was first described by Kruse (1959) from three species of penaeid shrimp in Florida, this worm was probably first discussed by Woodburn et al. (1957), who found "a larval trypanorhynchan cestode" in the hepatopancreas area of penaeid shrimp all along the west coast of Florida as well as near the Tortugas. Hutton et al. (1959) confirmed this distribution and further identified the worm as *Prochristianella* sp.

It is possible that the larval trypanorhynch cestode noted by Sparks and Mackin (1957) in *Penaeus setiferus* from Barataria Bay, Louisiana is *Prochristianella penaei*. However, it is not possible to confirm this point on the basis of their published account.

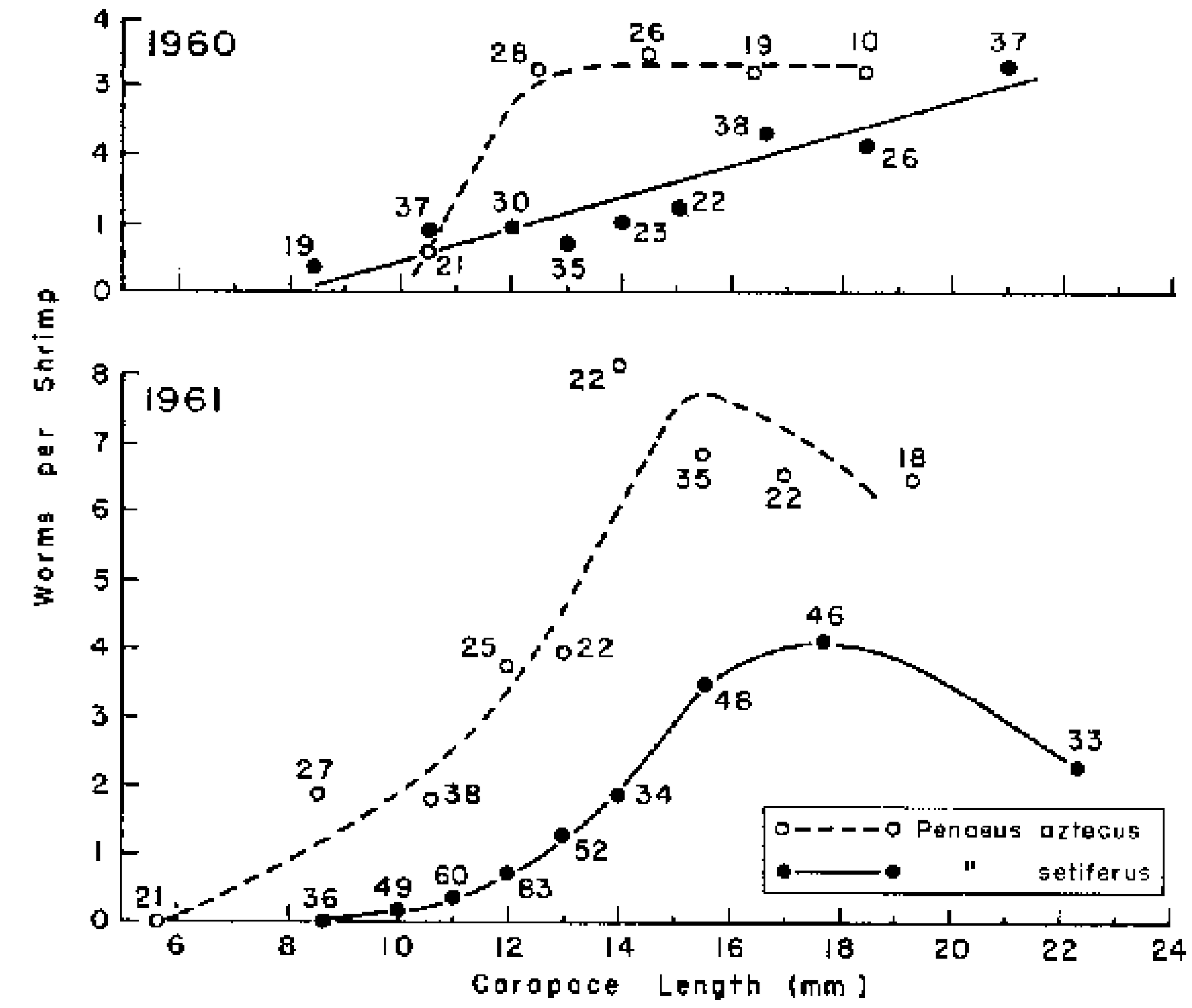


FIGURE 4. Intensity of *Prochristianella penaei* infection in shrimp of various sizes from Clear Lake. The number of shrimp represented by each point is indicated by the number adjacent to it.

In regard to the relative incidence of this parasite in penaeid shrimp of the Gulf of Mexico, it should be noted that Hutton et al. (1959) found *P. penaei* plerocerci in 63% of 295 *Penaeus duorarum* taken from various locations on the Florida west coast and concluded: "The larva of *Prochristianella* sp. has been found in shrimp from all areas and thus far does not appear to be of value in migration studies." Sampling in three locations within the northernmost portion of the Florida west coast, Kruse (1959) found 94% of 301 shrimp (including *Penaeus setiferus, P. aztecus*, and *P. duorarum*) to be infected, with each species having over 90% incidence. The striking variability between biweekly samples shown in the present work suggests that more intensive sampling during comparable seasonal periods will be necessary to compare the incidence of this cestode in shrimp from different areas. Adequate incidence data for various bays and offshore areas of the Gulf of Mexico would be of considerable interest in determining the potential utility of *Prochristianella penaei* as a biological shrimp "tag."

The data indicate a relationship between size of Clear Lake shrimp and incidence of infection with *P. penaei*. Tapeworm incidence increased with size of host in both species of shrimp (Fig. 3). The fact that this pattern exists for the estuarine portion of the shrimp life cycle indicates that shrimp entering Clear Lake tend to be much more lightly infected with *P. penaei* than those leaving the bay to begin their offshore movement. These results indicate that shrimp frequently acquire the infection within Clear Lake.

The ecological implications of these findings were considered in seeking the final host of this cestode. If the infection of shrimp occurs in the low salinity waters of Clear Lake, it is reasonable to assume that the shark or ray harboring the adult worm is a common inhabitant of brackish water (in which infection of the first intermediate host must occur). *Dasyatis sabina*, the commonest sting ray in Texas bays seems to satisfy this requirement. Discussing this ray, Bigelow and Schroeder (1953) noted: "The salinity of the water influences its distribution but little if at all, for it occurs throughout the entire range from fresh water up to full oceanic salinity. . . ." Several specimens of *D. sabina* from Galveston Bay were examined and found to contain adult *Prochristianella penaei* in the spiral valve. Although the first worm specimens, taken in May 1960, had scarcely developed beyond the scolex, they were completely excysted from the blastocyst and actively attaching to the spiral valve mucosa. Specimens collected in August 1963 showed more complete development, including mature segments. Identifications were made on the basis of several critical characters of tentacular structure and armature, following Dollfus (1946) and Kruse (1959): (1) presence of basal tentacular swelling with typical hook pattern; (2) presence of a longitudinal row of very large hooks on the internal metabasal tentacular surface; and (3) smaller hooks arranged in rows, and diminishing in size along the rows which extend from the internal to the external tentacular surface. Kruse (personal communication) has confirmed my identification of the adult worm and informed me that he has independently found adults in *D. sabina* since his earlier work (1959), which showed several specimens of that ray to be negative for adult *Prochristianella penaei*. Observations on the food habits of this ray, together with further details of the adult tapeworm's morphology will be published elsewhere.

Since no life cycles have been experimentally completed among the Trypanorhyncha, we can only assume that the observations of Ruszkowski (1932, 1934) and Riser (1956) may be representative of this order of tapeworms. If so, a procercoid stage of *P. penaei* exists, probably in small invertebrate-inhabiting, estuarine waters.

In addition to the obvious parasitological interest in completing this trypanorhynch life cycle, such work may have important applications in shrimp ecology. Due to the effective shredding action of the gastric mill in shrimp, attempts to gain food habit information using routine stomach analysis methods have not produced very useful results. Gut contents consist either of fragments tough enough to withstand the mill action (such as bits of mollusk shell, crustacean exoskeleton, or annelid setae) or of the amorphous material to which softer dietary portions have been reduced. Such substances are very difficult or impossible to identify. As a result, there is very little definitive information on feeding habits of shrimp. It is possible that completion of the life cycle of *P. penaei* will provide valuable information relating to this problem. The rapidity with which this tapeworm is acquired by shrimp after they enter Clear Lake indicates that the previous host may be an important natural food of shrimp.

A number of intriguing questions are posed by the infection data presented above. For example, it is clear that in both 1960 and 1961, *Penaeus aztecus* of a given size almost always contained more worms per shrimp than did *P. setiferus* of the same size (Fig. 4). Are these striking differences between shrimp species in intensity of infection due to (1) variable seasonal availability of infected first intermediate hosts combined with the difference in seasonal abundance of white and brown shrimp in Clear Lake; (2) food habit differences between species of shrimp; or (3) differences in susceptibility to infection between shrimp species? Other questions may be raised concerning the apparent "leveling off" of infection intensity in *P. aztecus* above 14 mm in carapace length. Is this due to change in food habit or increase in immunity? Some of these questions have led to work now in progress which includes the examination of Clear Lake bottom samples for small, procercoid-infected invertebrates, and the holding of shrimp and rays in the laboratory to effect completion of the life cycle of *Prochristianella penaei* under controlled conditions.

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